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MAXIMUM BACKGROUND NOISE LEVELS ON AUDIOMETRIC ROOMS: A CASE OF STUDY

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ABSTRACT
Ambient noise level requirements for audiometric rooms clearly depend on the field of application. This gives rise to proper characterization of audiometric rooms and their conformance to national or international standards. A comparison between values stated in standards ISO8253-1.1989 and ANSI-S3.1-1991 (Maximum permissible ambient noise levels for audiometric test rooms) is performed from 31, 5 Hz to 8 kHz. Experimental studies are though focused on the frequency interval of 125 Hz to 8000 Hz using maximum, minimum and equivalent sound pressure levels. Each data set consisted of 20 hours of continuous measurements, analized on one-third octave and octave bands, for different ambient conditions (e.g., air-conditioning On and Off). Measurement uncertainties may lead to non-conformances on frequency bands from 100 Hz to 1600 Hz, specially in places whose barometric pressures vary from reference conditions. Sound pressure levels due to ambient noise for audiometry tests with cover and uncover ears require a more thorough uncertainty estimation at 125 Hz.

1 - INTRODUCTION
Ambient noise level requirements for audiometric rooms clearly depend on the purpose of application [1,2], [6], e.g., ears covered or ears not covered. This gives rise to proper characterization of audiometric rooms and their conformance to national or international standards. A comparison between values stated in standards ISO8253-1.1989 (Acoustics − Audiometric test methods − part 1 Basic pure tone air and bone conduction threshold audiometry) and ANSI-S3.1-1991 (Maximum permissible ambient noise levels for audiometric test rooms) is performed from 31,5 Hz to 8 kHz. Experimental studies are though focused on the frequency interval of 125 Hz to 8000 Hz using maximum, minimum and equivalent sound pressure levels. Ambient noise levels for frequency bands outside the above interval require further research, it is known that at lower frequencies vibration effects and bone conduction become an issue, while hearing tests at frequencies above 8 kHz is still a being studied and no standardized criteria [2] is available regarding maximum background SPL regarded as ambient noise.
Maximum background noise levels stated in ISO8253-1.1989 for audiometric rooms versus their corresponding ANSI S3.1-1991 ambient noise levels for the same frequency intervals are shown in figure 1. It turns out that ISO8253-1 specifies larger background noise levels, which would imply less tighter requirements on audiometric rooms construction although a more thorough room characterization. Because of that, this work takes ISO8253-1 as the main reference.

2 - MEASUREMENT RESULTS AND ANALYSIS
Measurements were performed on an audiometric test room at CENAM's facilities seeking to establish its compliance respect to international standards for hearing test rooms. CENAM's audiometric environment consist of two separate rooms, a patient's room and an operator's room, figure 2 shows their approximated distribution and dimensions. Patient's room has carpeted floor and walls, and a rigid door, following some general considerations given in ANSI S3.1-1991. Patients can be monitored from the operator's rooms through a double glass window.
Measurements were taken using a two-channel real time analyzer [3, 4], B&K 2144 and two half-inch Norsonic 1220 microphones. Measurements shown in figures 3a to 3d were obtained with the microphones

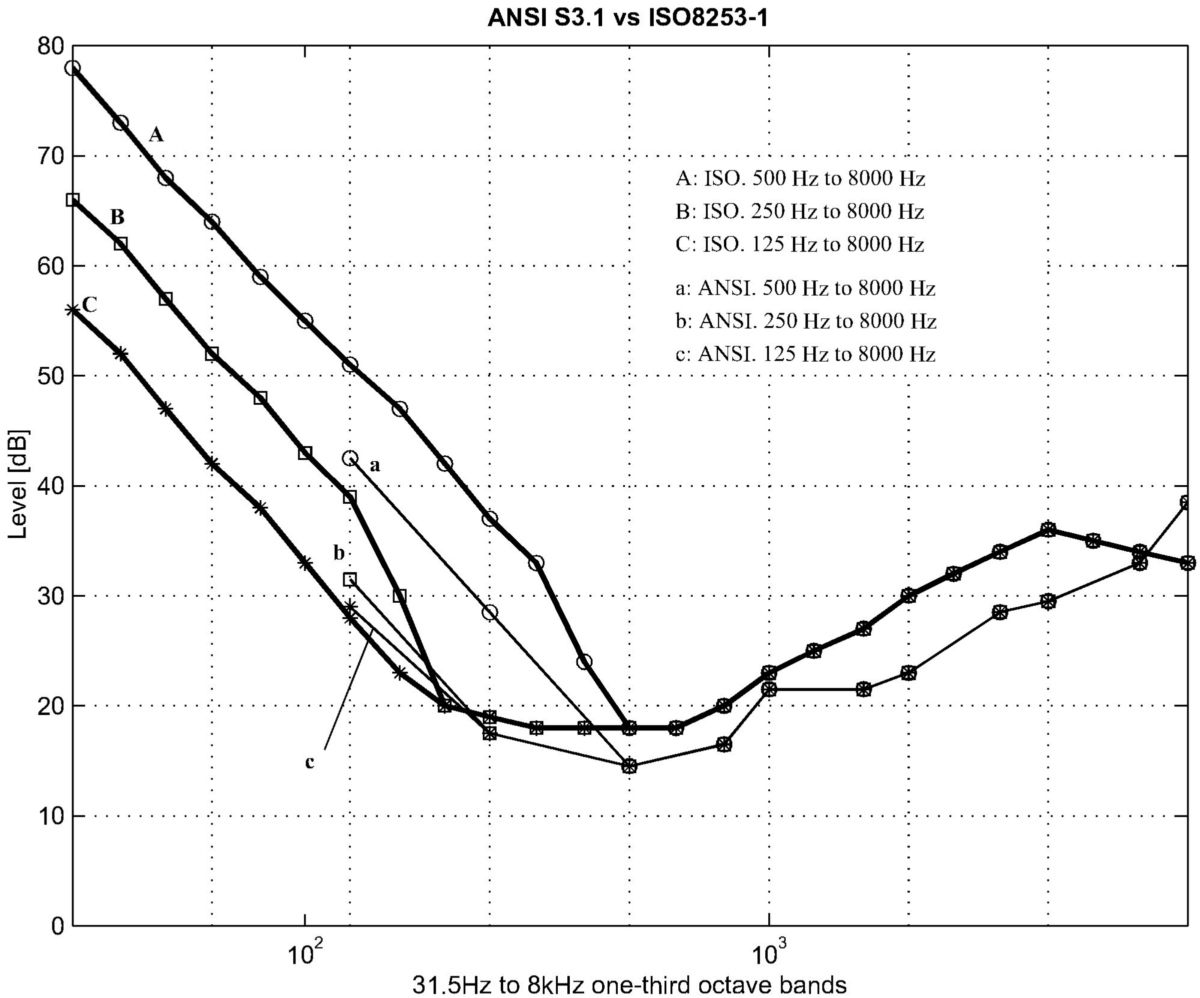

Figure 1: SPL ISO 8253-1 vs ANSI S3.1.

in position label A1, i.e., the patient's position. Position label B1 corresponds to the operator's position. All measurements were performed using heights of 1,25 m. Additional measurements were taken with microphones in positions A2, B2 and A3, B3. See figures 4a, 4b, 5a and 5b.
Special attention was given to measurements in the patient's room, with and without its heating and ventilation air-conditioning system (HVAC) turned on. Each data set consisted of 20 hours of continuous measurements taking averages every five minutes. Data analysis was performed on one-third octave and octave bands for different ambient conditions (e.g., normal operation, transient noisy ambient sources, HVAC On and Off). Figures 3 to 7 show SPL measurements inside the patient's room. It can be observed that when the air conditioning system is turned off, background noise levels decay substantially; ambient noise in some frequencies have decays larger than 10 dB, as shown on figure 7.
Taken into account such SPL reduction when HVAC system is off, further measurement sets were taken under "normal" conditions of operation, but with HVAC system switched off. For these later sets of measurements it was used a averaging time of one minute, and another positions were chosen for the microphones, (A2, B2 and A3, B3, see figure 2). Results form theses measurements are shown in figures 4 and 5.

3 - REMARKS FOR FURTHER STUDY ON ACTUAL AUDIOMETRY TESTS

Despite the fact that conformance of an audiometric room might be achieved respect to ISO or ANSI standards, it turns out that many commercial audiometers have resolutions of 5 dB, [5] which bring the issue of how critical the conformance criteria really is when using much better measuring capabilities, e.g., with resolutions of +/- 1 dB.
A straightforward setup to address this issue is shown on Fig. 6, where y_L corresponds to responses from the left ear, similarly y_R are responses from the right ear. On the other hand, e_1, e_2 are electrical

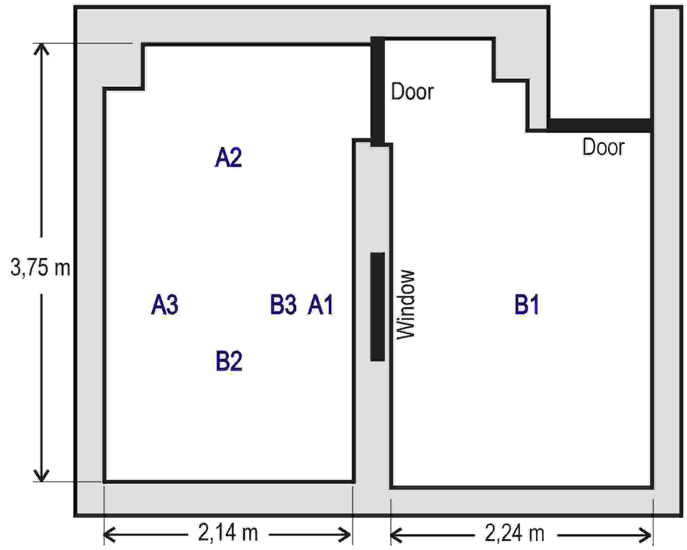

Figure 2: CENAM's audiometric room.

noises affecting the response of left and right ears, respectively. u_L and u_R are the sound levels applied to the left and right ears while n_1 and n_2 are the background noise levels coming in as an interference while performing audiometric tests. A simplified model to express their relationship may be set as,

$$\begin{bmatrix} y_L \\ y_R \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} S_1 & O \\ O & S_2 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} S_1 & O \\ O & S_2 \end{bmatrix} \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} \tag{1}$$

Considering a hearing test room whose background noise levels n might turn out to be above maximum ambient noise levels n_S by a quantity Δn, Eq. 1 may be expressed as

$$\begin{bmatrix} y_L \\ y_R \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} S_1 & O \\ O & S_2 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} S_1 & O \\ O & S_2 \end{bmatrix} \begin{bmatrix} \Delta n_1 \\ \Delta n_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where $r_1 = u_1 + n_{S1}$ and $r_2 = u_2 + n_{S2}$ which correspond to sound pressure levels applied on audiometric rooms satisfying conformance criteria for maximum background noise levels. As an attempt to quantify the effect of noise levels above the maximum limits, as in the case of CENAM's audiometric room having its HVAC turned on, follows that

$$\underline{y}_{on} - \underline{y}_{off} = \underline{AS}\Delta\underline{n}$$

where y_{on} and y_{off} come from sound pressure measurements having air-conditioning on and off respectively; matrices A and S correspond to the coupling of hearing capabilities between the two ears. In the case of a maniqui, Δn can be obtained from,

$$\Delta\underline{n} = \underline{S}^{-1}\left(\underline{y}_{on} - \underline{y}_{off}\right)$$

4 - CONCLUSIONS

Air-conditioning system represents the main ambient noise source on CENAM's audiometric room, which leads to non-conformances on frequency intervals going from 125 Hz to 1600 Hz. Operation without the air-conditioning system, maximum background noise levels are below those of ISO8253-1 and conformance is achieved from 125 Hz to 8 kHz. Although noise levels at 125 Hz are very close to the maximum levels allowed. A proper use of such audiometric room would require turning off its air conditioning system, unless it might be modified.

REFERENCES

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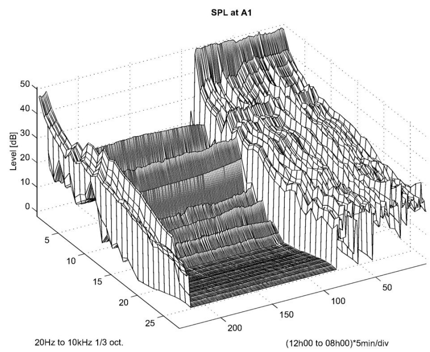

Figure 3(a): SPL inside patient's room.

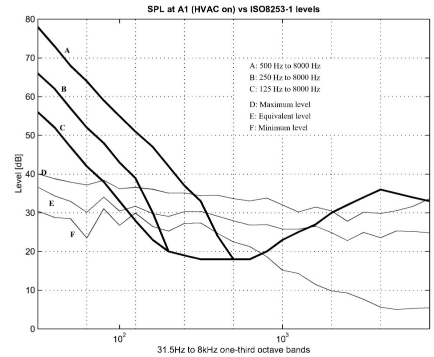

Figure 3(b): Typical ISO 8253-1 levels vs measured data for HVAC on.

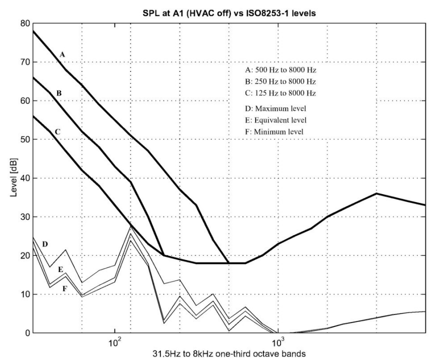

Figure 3(c): Typical ISO 8253-1 levels vs measured data for HVAC off condition (whole night).

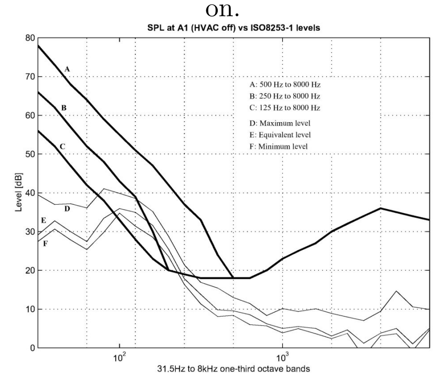

Figure 3(d): Typical ISO 8253-1 levels vs measured data for HVAC off condition, normal working day.

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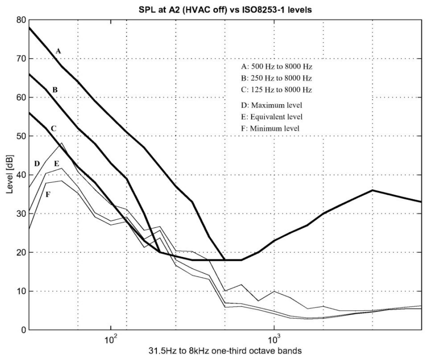

Figure 4(a): Typical ISO 8253-1 levels vs measured data for HVAC off condition (whole night).

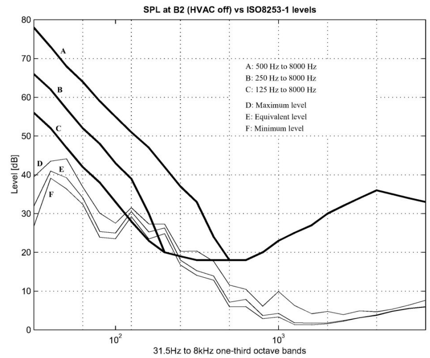

Figure 4(b): Typical ISO 8253-1 levels vs measured data for HVAC off condition, normal working day.

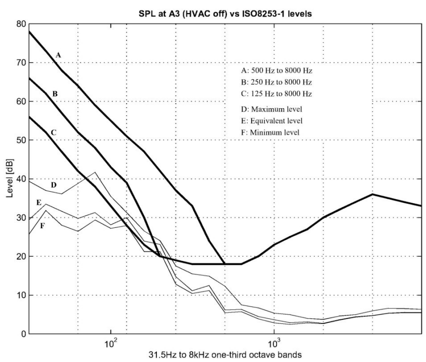

Figure 5(a): Typical ISO 8253-1 levels vs measured data for HVAC off condition (whole night).

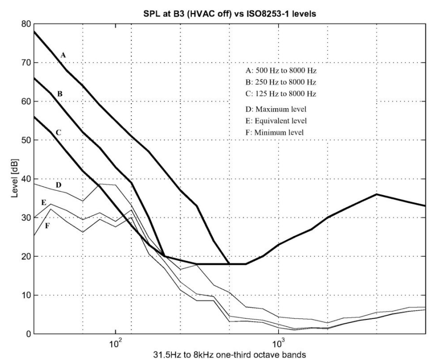

Figure 5(b): Typical ISO 8253-1 levels vs measured data for HVAC off condition, normal working day.

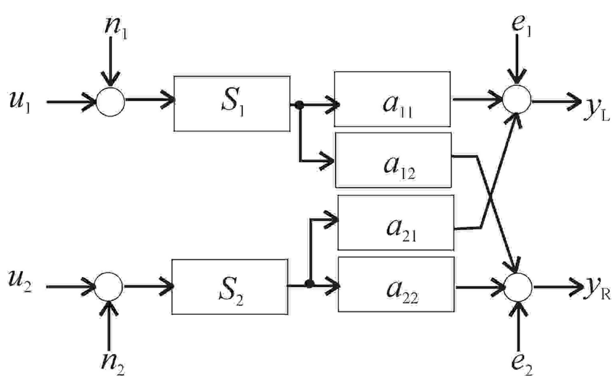

Figure 6: Proposed model to evaluate the effect of background noise in audiometric tests results.

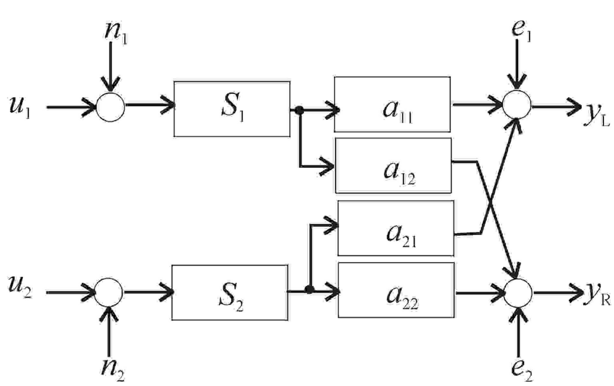

Figure 7: Typical noise decay with HVAC system on and off..